(12) UK Patent Application (19) GB (11) 2 252 295 (13) A

(43) Date of A publication 05.08.1992

(21) Application No 9102103.0

(22) Date of filing 31.01.1991

(71) Applicant
James Daniel Davidson
Field End, Market Lane, Blundeston, Lowestoft, NR32 5AP, United Kingdom

(72) Inventor
James Daniel Davidson

(74) Agent and/or Address for Service
Keith W Nash & Co
Pearl Assurance House, 90-92 Regent Street, Cambridge, CB2 1DP, United Kingdom

(51) INT CL[5]
B66C 13/30 23/53

(52) UK CL (Edition K)
B8H HBA H202 H217 H553
G3R RA34 RA35 RBA29
U1S S1871 S2182

(56) Documents cited
GB 1357197 A US 4238037 A US 3489293 A

(58) Field of search
UK CL (Edition K) B8H HBA HBB HFA, G3N NGBE2 NGBX N265X, G3R RBA29
INT CL[5] B66C 13/18 13/22 13/30 23/52 23/53 23/58
Online databases: WPI

(54) **Offshore crane control system**

(57) An offshore crane control system for a crane having a base body 4 mounted for rotation under the control of slew motors 5 operable under operator control, wherein an automatic control system is incorporated in the drive to the slew motors in such a manner that control inputs from the operator and from motion sensors are used to provide a signal for required movements of the suspended load to help eliminate wind-, wave-, and impact-induced movements. Pref. the control device receives inputs from sensors (e.g. accelerometers, position, orientation or rotation devices or strain gauges) measuring motion of the hull, crane and load and from configuration sensors as well as from the operator. The sensor inputs can be processed to provide dynamic and static components or roll, sway, slew and swing.

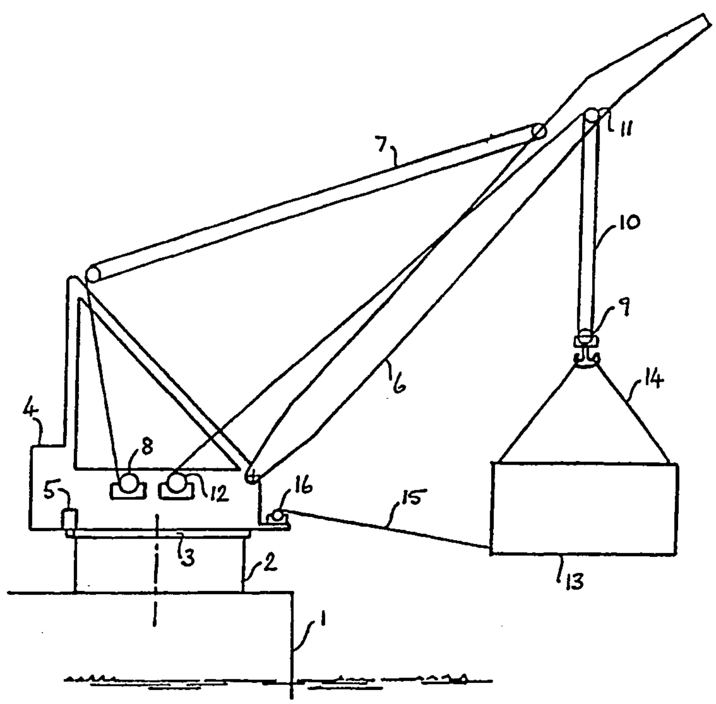

Fig 1

GB 2 252 295 A

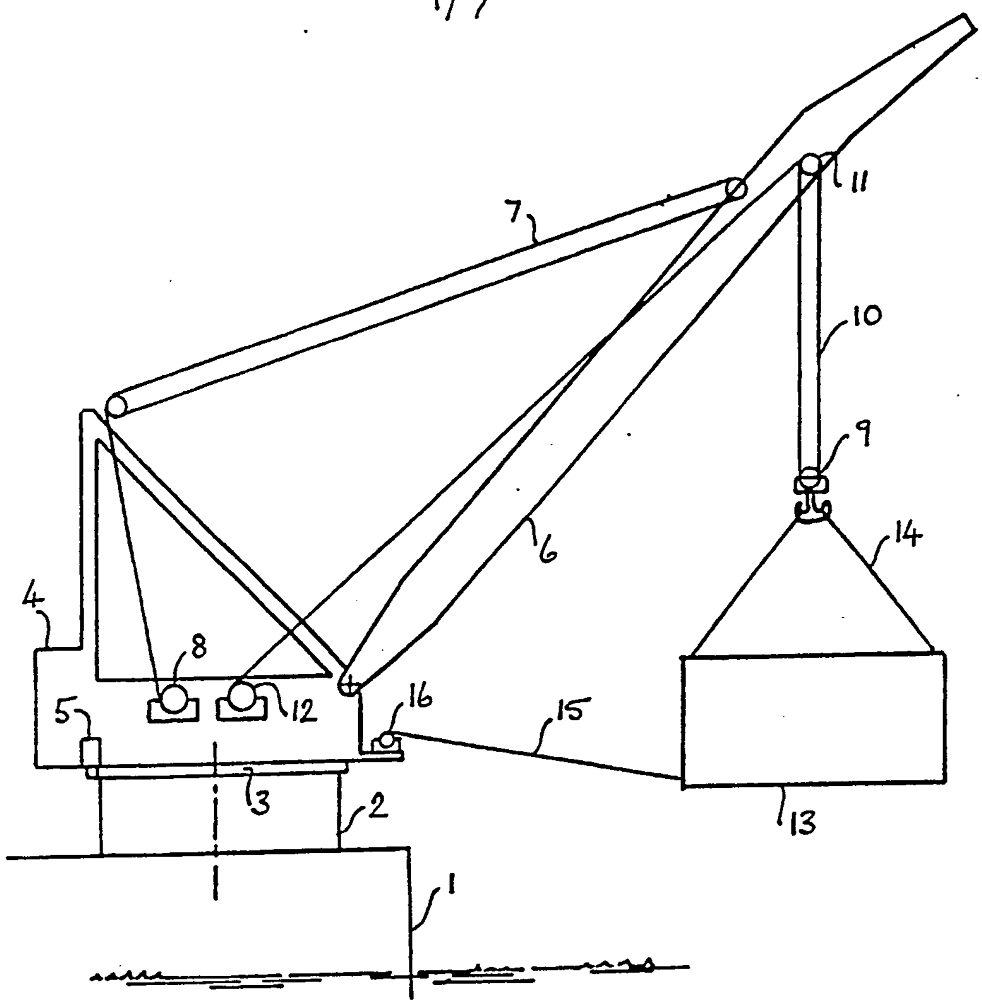

Fig 1

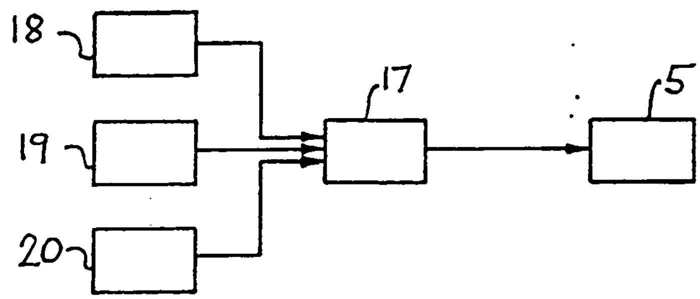

Fig 2

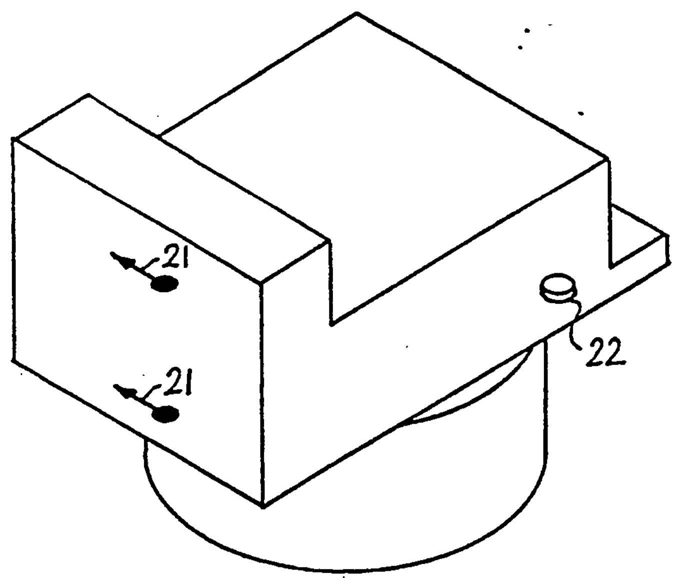

Fig 3

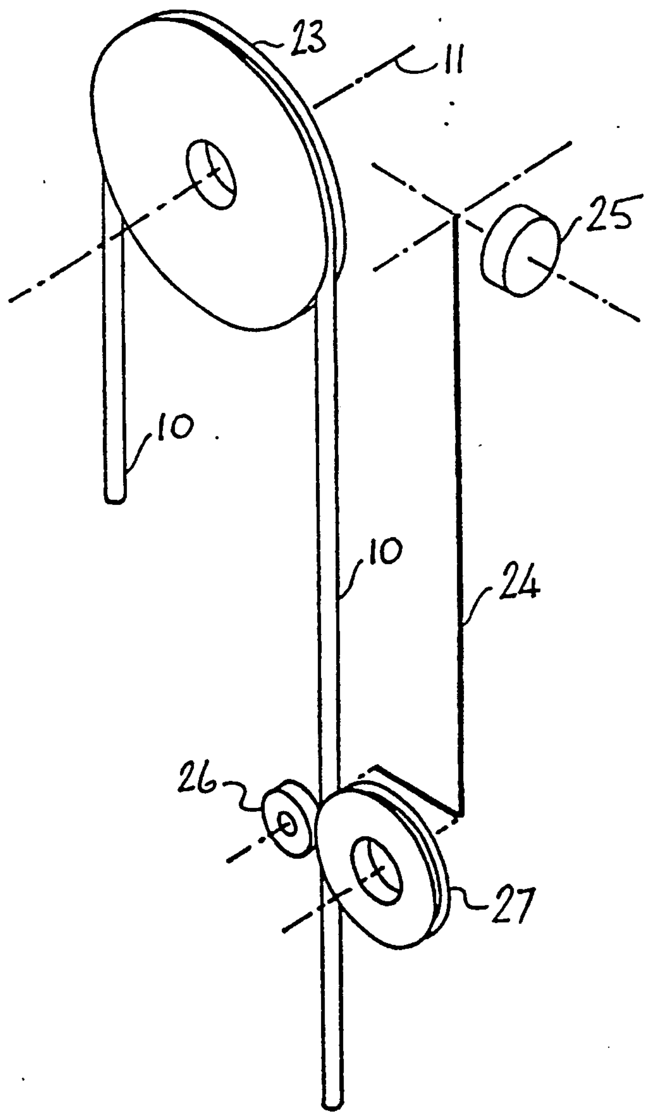

Fig 4

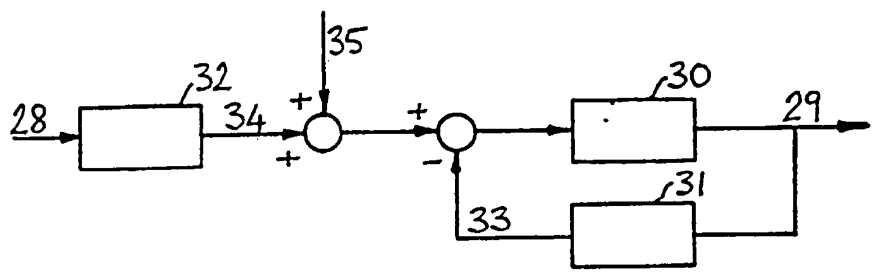

Fig 5

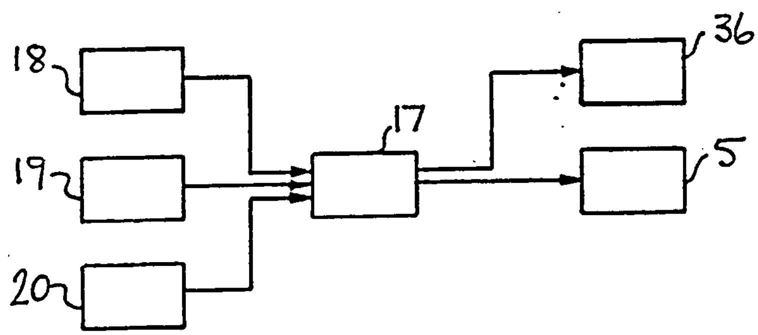

Fig 6

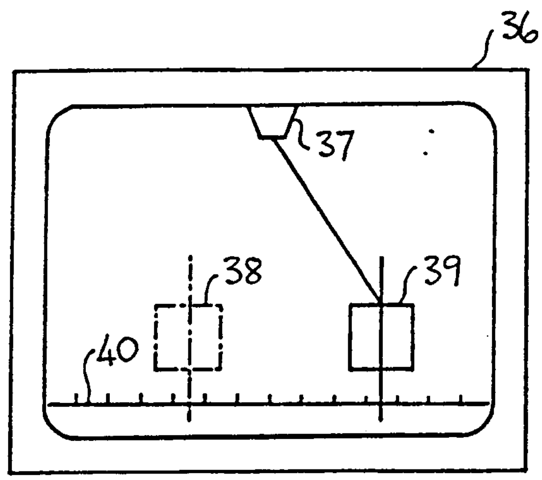

Fig 7

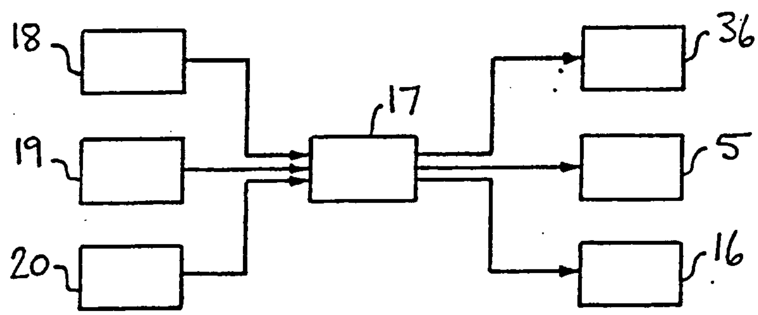

Fig 8

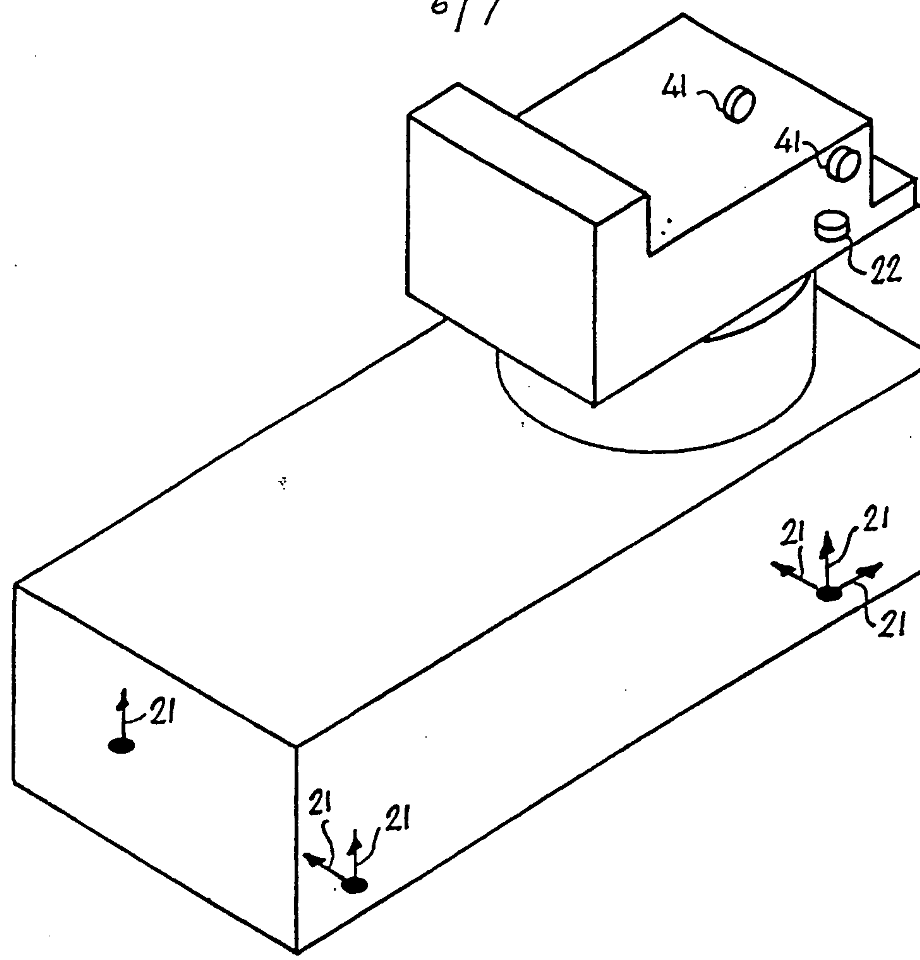

Fig 9

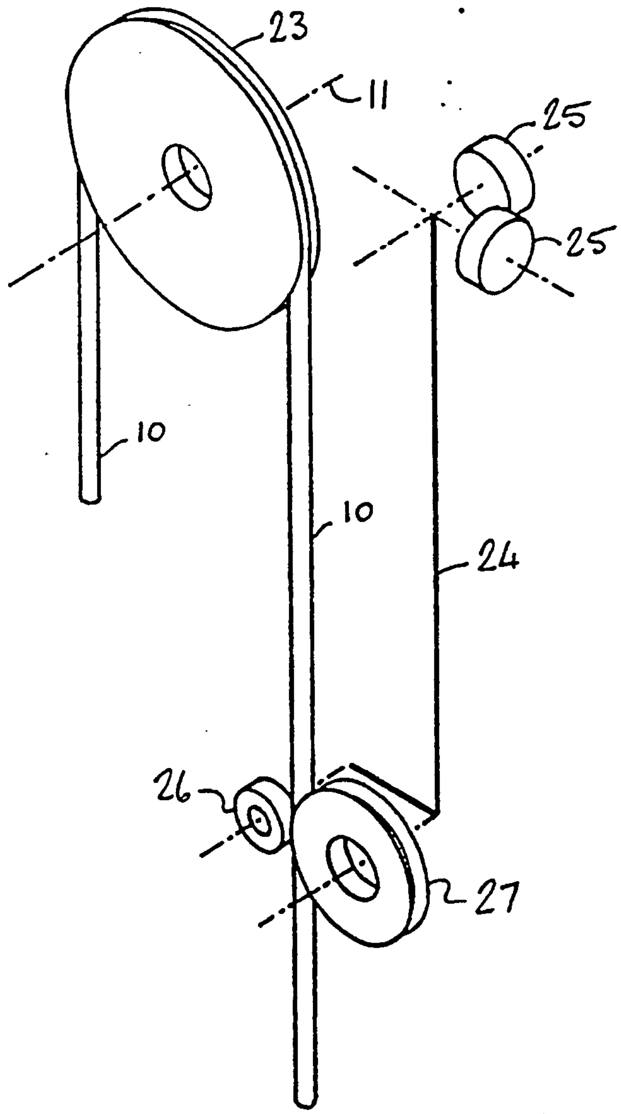

Fig 10

Title: Offshore Crane Control System

Field of the Invention

This invention relates to an offshore crane control system.

Background to the Invention

Heavy lift cranes mounted on floating vessels experience unwanted motion of the suspended load when working offshore. This movement is due to the action of wind and waves on the system comprising the hull, the crane and the suspended load. The load can move vertically, radially and tangentially. Attempts to alleviate the vertical motion have been the subject of a number of patents and published papers, generally under the heading of heave compensation. On many cranes there is no heave compensator and the operator has to choose carefully the time at which he picks or places a load so as to minimise impact due to the vertical motion of the load. Radial motion of the load, towards or away from the centre of rotation of the crane, is often controlled by tugger winches mounted on the rotating frame of the crane. Tangential or side to side motion of the load is damped out by carefully timed slewing of the crane, under the control of the operator. The extent to which this damping is effective is governed by the skill of the operator.

The job of the operator of such a crane is thus a highly

demanding one. As well as performing the functions of the operator on a land based crane, he has to cope as well as he can with the considerable extra workload introduced by the offshore environment.

It is a primary object of the present invention to provide a control system for an offshore crane which simplifies the task of the operator in controlling the crane and its load.

The Invention

According to the invention, there is provided an offshore crane control system for a crane having a base mounted for rotation under the control of slew motors operable responsively to operator controls, comprising a control device interposed in the connection between the operator controls and the slew motors and receiving inputs from motion sensors such that the operator control inputs also supplied to the device are transformed into control signals for the slew motors representing demands for movement of the suspended load, and wind-, wave- and impact-induced swinging movements of said load are at least substantially minimised.

The invention thus provides an improved offshore crane or floating crane incorporating an automatic control system in the slew drive, such that the crane operator control inputs are treated as demands for movement of the suspended load, and wind-, wave- and impact-induced swinging of the suspended load is substantially eliminated or at least minimised.

Preferably, the motion sensors sense movements of the hull

carrying the crane, of the crane body and of the suspended load. The control device preferably also receives inputs relating to the configuration of the crane, including the magnitude of the suspended load, the length of the load lines, the boom angle, the mean slew angle and the distance from the load carrying hook to the centre of gravity of the suspended load. The device may include a keyboard for entry of at least some of said additional inputs.

The sensors preferably include accelerometers mounted on the rotary base of the crane in vertically spaced relationship for measuring horizontal acceleration and roll acceleration, a rotation encoder for measuring rotation of the crane body relative to the hull, and a sensing means for measuring the angle of departure of the load lines from the boom.

Desirably, the control device is able to process the inputs from the motion sensors to derive dynamic components for roll, sway, slew and swing, as well as static components for roll, slew and swing.

In a preferred system the movement of the operator controls is treated as a demand for load velocity and is integrated to determine the target position for the load. Conveniently, therefore, the system includes an operator display for indicating the target load position relative to the current load position.

In a preferred system for a crane which has load tugger winches mounted on the crane body, additional sensors also provide inputs to the control device, including inputs relating to degrees of freedom of the load, and the

control device also provides control signals for motors driving the tugger winches. Such a system may have six accelerometers mounted on the hull, and sensing devices mounted on the tuggers for measuring rope travel.

Description of Embodiments

The control system in accordance with the invention will now be exemplified with reference to the accompanying drawings, in which:-

Figure 1 shows a typical offshore crane;

Figure 2 shows a crane control system in block diagram form;

Figures 3 and 4 show sensing devices;

Figure 5 shows a part of the control system, also in block diagram form;

Figure 6 shows a modification of the diagram of Figure 2 and incorporates an operator display;

Figure 7 shows a possible embodiment of operator display;

Figure 8 shows a modification of the diagram of Figure 6, for a crane having tugger winches; and

Figures 9 and 10 show sensing devices for use in the control system of Figure 8.

An offshore crane typical of those currently in use is illustrated in Figure 1. The hull 1 of a vessel carrying

the crane may be of any configuration; barge shaped, ship shaped, and semi-submersible hulls are commonly used. A tub structure 2 supports a slewing rail or swing circle 3 on which is mounted for rotation a base 4 carrying the frame of the crane. Slew motors 5, mounted on the rotary base, drive pinions which engage in a toothed rack mounted on the tub structure. The slew motors 5 control rotation of the rotating base and frame 4 on the swing circle 3.

The crane boom 6 is pivoted at its foot to the rotary base 4 and supported by wire rope boom lines 7 connected back to boom hoists 8. Operation of the boom hoists raises or lowers the boom.

A load block and hook assembly 9 is supported by wire rope load lines 10 connected back through a fixed pulley block 11 to load hoists 12. Operation of the load hoists raises or lowers the load. The load 13 is suspended by slings 14 from the hook assembly 9.

Wire rope tugger lines 15 are connected from the load 13 back to tugger hoists 16, of which there are generally two, mounted on the rotating base of the crane 4. Operation of the tuggers, provided the lines are taut, controls movement of the load towards or away from the crane, and rotation of the load about a vertical axis.

An automatic control system for the slew motor drives is illustrated in Figure 2. A control computer 17 receives signals from motion sensors 18, which measure motion of the hull, the crane, and the load, from configuration sensors 19, and from the crane operator controls 20. The computer sends signals to the slew drives 5. The arrangement shown in Figure 2 differs from the arrangement

in a conventional crane, where there is a direct link between the operator controls and the slew drives. In Figure 2 the direct link is broken, with a control computer interposed betwen the operator controls and the slew motors, and the control computer accepts inputs additional to those made by the driver, including measurements of the motion of the hull on which the crane is mounted.

The motion sensors 18 are an array of sensing devices which include one or more accelerometers and may also include position, orientation or rotation measuring devices, and strain gauges. In one possible realisation of the invention, the degrees of freedom measured are roll about, and sway perpendicular to, the longitudinal axis of the crane's rotating frame, slew of the rotating frame on the swing circle, and swing of the load perpendicular to the longitudinal axis of the crane's rotating frame. The words roll and sway here are used in the conventional ship motions sense as if the longitudinal axis of the crane were the longitudinal axis of the vessel. If the crane boom were over the bow or stern of the vessel, then roll measured for the crane would be the same as roll for the hull. If the crane boom were over the side of the vessel then roll measured for the crane would be the same as pitch for the vessel. Because a vessel rolls about an axis whose location is not fixed by any mechanical means at a known location, it is necessary to measure both roll and sway, effectively so that the location of the roll axis can be known. It is not necessary that motion in any of the relevant degrees of freedom be measured directly; a computer can readily derive direct values from indirect measurements. Measurements of hull motion, for example, can be made either on the hull or on the rotating frame.

Figures 3 and 4 show one suitable arrangement of the motion sensors 18.

Figure 3 shows sensing devices mounted on the rotary base and frame of the crane. Two accelerometers 21 are mounted vertically above one another, preferably at a large spacing, and orientated so as to measure horizontal acceleration perpendicular to the longitudinal axis of the crane. Initial calibration or alignment of the accelerometers is performed with vessel motion eliminated, either in dry dock, or afloat but touching keel blocks. A rotation encoder 22 mounted at the swing circle measures rotation of a pinion engaged in the toothed rack on the tub structure.

Figure 4 shows a device which measures the angle of departure of the load lines from the boom. Sheave 23 is one of the sheaves in the fixed pulley block 11. It supports two parts of a wire rope load line 10. An arm 24 is mounted on pivots at its top end. The pivot axis parallel to the longitudinal axis of the rotary frame of the crane is instrumented with a rotation measuring device 25 so that the orientation of the arm can be transmitted to the control computer. At the bottom end of the arm, a spring loaded roller 26 holds an idler sheave 27 in contact with the load line 10. The arm 24 follows the orientation of the load line 10, and points towards the travelling block and the centre of gravity of the suspended load.

Suitable processing in the computer of the signals from the motion sensors derives dynamic components for roll, sway, slew and swing, and static components for all but sway. The processing techniques are standard in

navigation and ship motion work. The arrangement of sensing devices shown in Figures 3 and 4 is only one of a number of possible arrangements of such devices, from which the required motion analysis could be obtained.

The configuration sensors 19 measure system properties which change more slowly than the dynamics of the suspended load, or which are fixed for periods of time. These properties are the magnitude of the hookload, the length of the load lines, the boom angle, the mean slew angle, the distance from the hook to the centre of gravity of the suspended load, and the loading condition of the hull. Since the slew angle is also one of the dynamic variables measured by the motion sensors, the slew encoder input can be used, but with the input averaged over time. The hook to centre of gravity distance cannot conveniently be measured and may be entered into the computer by keyboard, switch selection or similar input device. The loading condition of the hull may also be entered by keyboard, switch selection or similar input device, or by interface with the ballast control system of the vessel.

The operator controls 20, typically including a joystick, also provide input to the control computer 17.

The function of the operator controls 20 is to define the response required of the suspended load, rather than the response required of the motors. Joystick displacement is treated as a demand for load velocity, and is integrated to find the required load position. The input from the operator thus effectively sets a target position for the load.

A block diagram of this part of the system is shown in

Figure 5. Input 28 is the operator input, while output 29 is the actual position of the hull, crane and load. Block 30 is the system comprising hull, crane and load. Blocks 31 and 32 together represent the control computer and the slew motors, their outputs being slew torques 3 and 34. Torques 33 and 34 exist separately only in the block diagram description; in the physical realisation blocks 31 and 32 together generate one torque, the difference between torques 33 and 34. Input 35 is the set of forces tending to disturb the system due to wind, wave and impact.

In one possible realisation, the slew torque 33 generated by block 31 is proportional to the displacements in the various degrees of freedom and to their first two derivatives. Some of the constants of proportionality may be zero. One of the constants of proportionality represents slew stiffness, so application of a constant slew torque would result in a constant slew displacement. Block 32 integrates the demanded slew velocity to determine the required slew position, and develops sufficient slew torque to overcome the resistance due to the slew stiffness term in block 31 and to achieve the desired load displacement. Block 31 can be thought of as a governor or regulator trying to return the load to a fixed position, while block 32 can be thought of as a device driving the load to a steady position to one side of the fixed position. While the computing function of blocks 31 and 32 could be realised using analogue computers, the constants of proportionality used are valid for only a small range of configurations of the crane. For a useful range of crane configurations the constants of proportionality need to be able to be altered, and this can more conveniently be accomplished using digital

techniques. Suitable constants of proportionality may be determined by an iterative procedure using a mathematical model of the hull-crane-load system.

The above-described proposal, namely a digital equivalent of an analogue technique, is only one way in which the blocks 31 and 32 can be given suitable characteristics. The development of suitable characteristics for the blocks 31 and 32 is a problem which can be solved by standard control engineering techniques, and some of the possible solutions will have no analogue equivalent.

Because a long pendulum swings slowly compared to the reaction time of the human operator, the operator will be aware that motion of the suspended load is delayed compared to the control input. It is therefore possible for the operator to demand more response than he actually requires, the result being operator induced swinging of the load. This undesirable system characteristic can be eliminated if the operator is able to see the target position he has set, which is generally distinct from the instantaneous position of the load. A block diagram of the system, incorporating an operator display, is shown in Figure 6. The block diagram is generally similar to that shown in Figure 2 and described above but with the addition of the operator display 36. The operator display shows the target load position and the current load position in such a way that they can readily be compared.

Figure 7 shows one possible way in which the operator display 36 might be configured. A reference symbol 37, fixed in the centre of the display, represents the position of the crane boom tip. A symbol 38, movable from side to side, represents the target position of the load.

Another symbol 39, represents the current position of the load. A scale 40 shows circumferential distances at the radius of the load.

A different possible way of configuring the display 36 would be to use coloured lights, the number illuminated indicating the separation between load and target position, the colour indicating whether the target was to the left or right of the load. A possible refinement of this would be so to arrange the lights that they were reflected off a partially silvered glass plate in the line of sight of the operator. He would then be able the see the display without taking his eyes off the load.

In a more complete realisation of the invention, the tuggers are brought under automatic control as well as the slew drives, so that all horizontal motion of the suspended load is substantially eliminated. A block diagram of a system incorporating this feature is shown in Figure 8. This is generally similar to Figure 6 except that there are more inputs to the computer 17 from the motion sensors 18, the configuration sensors 19 and the operator controls 20, as well as new outputs from the computer to the tuggers 16. In this realisation, the degrees of freedom measured are the six degrees of freedom of the hull, slew of the rotating frame on the swing circle, and three degrees of freedom for the load, these three being the two horizontal translations and rotation about a vertical axis. Figures 9 and 10 show a suitable arrangement of the motion sensors 18.

Figure 9 is similar in principle to Figure 3 except that the accelerometers 21, of which there are now six, are mounted on the hull, and there are in addition sensing

devices 41, mounted on the tuggers, which measure rope travel.

Figure 10 is generally similar to Figure 4 except that both of the pivot axes are instrumented with rotation encoders 25.

The configuration sensors 19 for the system described with reference to Figure 8 are generally similar to those for the system described in Figure 2, but with the addition of a capability to input the location of the tugger attachment points in relation to the centre of gravity of the suspended load.

The operator controls 20 for the system described in Figure 8 are generally similar to those for the system described for Figure 2, but with the addition of a joystick for each of the two tuggers. Again, the function of the tugger joysticks is to define the response required of the suspended load rather than the response required of the tugger motors.

Claims

1. An offshore crane control system for a crane having a base mounted for rotation under the control of slew motors operable responsively to operator controls, comprising a control device interposed in the connection between the operator controls and the slew motors and receiving inputs from motion sensors such that the operator control inputs also supplied to the device are transformed into control signals for the slew motors representing demands for movement of the suspended load, and wind-, wave- and impact-induced swinging movements of said load are at least substantially minimised.

2. A system according to claim 1, in which the motion sensors sense movements of the hull carrying the crane, of the crane body and of the suspended load.

3. A system according to claim 1 or claim 2, in which the control device also receives inputs relating to the configuration of the crane, including the magnitude of the suspended load, the length of the load lines, the boom angle, the mean slew angle and the distance from the load carrying hook to the centre of gravity of the suspended load.

4. A system according to claim 3, in which the device includes a keyboard for entry of at least some of said additional inputs.

5. A system according to claim 2 or claim 3 or claim 4, in which the sensors include accelerometers mounted on the rotary base of the crane in vertically spaced relationship for measuring horizontal acceleration and roll acceleration, a rotation encoder for measuring rotation of the crane body relative to the hull, and a sensing means for measuring the angle of departure of the load lines from the boom.

6. A system according to any of claims 2 to 5, in which the control device processes the inputs from the motion sensors to derive dynamic components for roll, sway, slew and swing, as well as static components for roll, slew and swing.

7. A system according to any of claims 1 to 6, in which movement of the operator controls is treated as a demand for load velocity and is integrated to determine the target position for the load.

8. A system according to claim 7, including an operator display for indicating the target load position relative to the current load position.

9. A system according to any of claims 1 to 8, for a crane which has load tugger winches mounted on the rotating base, wherein additional sensors also provide inputs to the control device, including inputs relating to degrees of freedom of the load, and the control device also provides control signals for motors driving the tugger winches.

10. A system according to claim 9, having six accelerometers mounted on the hull, and sensing devices

mounted on the tuggers for measuring rope travel.

11. An offshore crane control system substantially as hereinbefore described with reference to the accompanying drawings.

Patents Act 1977
Examiner's report to the Comptroller under Section 17 (The Search Report)

Application number 9102103.0

Relevant Technical fields

(i) UK Cl (Edition K) B8H,HBA,HBB,HFA,G3R,RBA29, G3N,NGBX,NGBE2,N265X

(ii) Int Cl (Edition 5) B66C 13/18,22,30,23/52,53&58

Search Examiner

D.MCMANN

Databases (see over)

(i) UK Patent Office

(ii) Online: WPI

Date of Search

21 May 1991

Documents considered relevant following a search in respect of claims

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
X	GB 1,357,197 (SIEMENS)	1
X	US 4,238,037 (AZOUTSEV ET AL)	1,2
X	US 3,489,293 (SALLOW)	1

Category	Identity of document and relevant passages	Relevant to claim(s)

Categories of documents

X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family, corresponding document.

Databases: The UK Patent Office database comprises classified collections of GB, EP, WO and US patent specifications as outlined periodically in the Official Journal (Patents). The on-line databases considered for search are also listed periodically in the Official Journal (Patents).

Published 1992 at The Patent Office, Concept House, Cardiff Road, Newport, Gwent NP9 1RH. Further copies may be obtained from Sales Branch, Unit 6, Nine Mile Point, Cwmfelinfach, Cross Keys, Newport, NP1 7HZ. Printed by Multiplex techniques ltd, St Mary Cray, Kent.